

1           2. The apparatus as set forth in claim 1, wherein the multi-dimensional equalizer  
2 combines the input signal vector with a vector error to determine a multidimensional  
3 steepest descent gradient, and further wherein the input signal vector is adjusted with the  
4 descent gradient to provide the output signal vector.

1           3. The apparatus as set forth in claim 2, wherein the equalizer determines the  
2 vector error based on the output signal vector and an input channel signal vector.

1           4. The apparatus as set forth in claim 3, further comprising an echo canceler,  
2 wherein the input signal vector is based on the input channel signal vector after it is  
3 adjusted with the echo canceler.

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cont 1           5. The apparatus as set forth in claim 3, further comprising a near end cross talk  
2 canceler, wherein the input signal vector is based on the input channel signal vector after  
3 it is adjusted by the near end cross talk canceler.

1           6. A method for canceling far end cross talk and intersymbol interference in a  
2 communication network, the method comprising:  
3           estimating a change in error between an input signal vector and an output signal  
4           vector;  
5           determining a multidimensional steepest descent gradient based on the change in  
6           error;  
7           adjusting the output signal vector using the descent gradient.  
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1           7. The method as set forth in Claim 6, wherein estimating the change in error  
2 between the input signal vector and the output signal vector includes determining the  
3 partial derivative of the error with respect to a tap matrix.

1           8. The method as set forth in Claim 7, wherein estimating the change in error  
2 between the input signal vector and the output signal vector includes updating the tap  
3 matrix by a vector amount that is proportional to the partial derivative of the error.

1           9. The method as set forth in Claim 8, wherein estimating the change in error  
2 between the input signal vector and the output signal vector includes assuming that the  
3 tap matrix is symmetric.

1           10. The method as set forth in Claim 7, wherein estimating the change in error  
2 between the input signal vector and the output signal vector includes performing vector  
3 operations.

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1           11. The method as set forth in Claim 7, wherein estimating the change in error  
2 between the input signal vector and the output signal vector includes passing the input  
3 signal vector through a series of unit delay operators.

1           12. A method for canceling far end cross talk and intersymbol interference in a  
2 communication network, the method comprising:  
3           compensating an output signal vector based on a plurality of tap matrices and an  
4           error vector signal, wherein the error vector signal is based on the  
5           difference between an input signal vector and the compensated output  
6           signal vector.

1           13. The method as set forth in Claim 12, wherein compensating the output signal  
2 vector includes applying a delay to the input signal vector.

1           14. The method as set forth in Claim 13, wherein compensating the output signal  
2 vector includes multiplying the error vector signal by the delayed input signal vector.

1 15. The method as set forth in Claim 14, wherein compensating the output signal  
2 vector includes generating the plurality of tap matrices based on a plurality of delayed tap  
3 matrices and the product of the error vector signal and the delayed input signal vector.

1 16. The method as set forth in Claim 15, wherein compensating the output signal  
2 vector includes generating the output signal vector based on the product of the delayed  
3 tap matrices and the delayed input signal.

1 17. The method as set forth in Claim 12, wherein compensating the output signal  
2 vector includes canceling echo from the input signal vector.

1 18. The method as set forth in Claim 12, wherein compensating the output signal  
2 vector includes canceling near end cross talk from the input signal vector.

1 19. An apparatus for canceling far end cross talk and intersymbol interference in  
2 a communication network, the apparatus comprising:  
3 a multi-dimensional equalizer, wherein the equalizer is operable to generate an  
4 output signal vector based on an error vector.

1 20. The apparatus, as set forth in claim 19 wherein the equalizer further includes:  
2 a vector delay operator coupled to generate a delayed input signal vector from an  
3 input signal vector.

1 21. The apparatus, as set forth in claim 20 wherein the equalizer further includes:  
2 a vector error operator for generating the error vector based on the delayed input  
3 signal vector and the difference between the output signal vector and the  
4 input signal vector.

1 22. The apparatus, as set forth in claim 21 wherein the equalizer further includes:  
2 a first matrix multiplication operator coupled to generate the product of the  
3 delayed input signal vector and the error vector.

23. The apparatus, as set forth in claim 22 wherein the equalizer further includes:  
a matrix summation operator coupled to receive the product from the first matrix  
multiplication operator, wherein the matrix summation operator is  
operable to add the product from the first matrix multiplication operator to  
output from a matrix tap unit delay operator.

24. The apparatus, as set forth in claim 23 wherein the output of the matrix tap  
unit delay operator includes a plurality of delayed tap matrices based on input from the  
matrix summation operator.

25. The apparatus, as set forth in claim 24 wherein the equalizer further includes:  
a second matrix multiplication operator coupled to receive input from the matrix  
tap unit delay operator and the vector data unit delay operator, wherein the  
second matrix multiplication operator is operable to generate another  
output signal vector based on the plurality of delayed tap matrices and the  
delayed input signal vector.

26. An apparatus for canceling far end cross talk and intersymbol interference in  
a communication network, the apparatus comprising:  
a decision feedback equalizer operable to determine a multidimensional steepest  
descent gradient to adjust matrix coefficients that are proportional to  
estimates of

$$\frac{\partial e_n}{\partial Q_k^{i,j}}, \text{ wherein } Q_k^{i,j} \leftarrow \left( Q_k^{i,j} - \mu \cdot \left( \frac{\partial e_n}{\partial Q_k^{i,j}} \right) \right).$$

27. The apparatus as set forth in Claim 26, wherein:

$$\frac{\partial e_n}{\partial Q_k^{i,j}} = 2 \cdot (Z_n^i - X_{n-p}^i) \cdot Y_{n-k}^j.$$

28. The apparatus as set forth in Claim 26, further comprising:  
a vector data unit delay operator coupled to receive an input vector  $Y_n$  from a communication channel;  
a vector error scaling operator for generating an error signal proportional to the difference between the output  $Z_n$  of the feedforward equalizer and the input  $X_n$  to the communication channel;  
a first matrix multiplication operator coupled to multiply input from the vector data unit delay operator and the vector error scaling operator;  
a matrix summation operator coupled to add the output from the first matrix multiplication operator to the output from a matrix tap unit delay operator, wherein the matrix tap unit delay operator receives input from the matrix summation operator; and  
a second matrix multiplication operator coupled to multiply input from the matrix tap unit delay operator and the vector data unit delay operator, thereby generating an output vector  $Z_{n+1}$ .

29. The apparatus, as set forth in Claim 28, wherein:  
the vector data unit delay operator passes a data vector  $Y_n$  through a series of unit delay operators to generate successive tap input data  $Y_n, Y_{n-1}, Y_{n-2}$ .

30. The apparatus, as set forth in Claim 29, wherein:  
the first matrix multiplication operator receives the  $1 \times N$  matrix  $Y_{n-k}$  from the unit delay operator and multiplies it with the  $N \times 1$  matrix of scaled vector error data  $(Z_n - X_n)$  from the vector error scaling operator.

31. The apparatus, as set forth in Claim 29, wherein:  
the matrix summation operator receives a  $N \times N$  adjustment matrix from the first matrix multiplication operator, adds the adjustment matrix to a  $Q_{n-k}$  matrix from the matrix tap unit delay operator, and outputs a corrected matrix  $Q_{n-k+1}$ .

1        32. The apparatus, as set forth in Claim 31, wherein the matrix tap unit delay  
2 operator receives the corrected matrix  $Q_{n-k+1}$  from the matrix summation operator, and  
3 introduces a one cycle delay to generate the  $Q_{n-k}$  matrix.

1        33. A device for canceling far end cross talk and intersymbol interference in a  
2 communication network, comprising:  
3        means for compensating an output signal vector based on a plurality of tap  
4        matrices and an error vector signal, wherein the error vector signal is  
5        based on the difference between an input signal vector and the  
6        compensated output signal vector.

1        34. The device as set forth in Claim 33, wherein the means for compensating the  
2 output signal vector includes means for applying a delay to the input signal vector.

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1        35. The device as set forth in Claim 34, wherein the means for compensating the  
2 output signal vector includes means for generating a product of the error vector signal  
3 and the delayed input signal vector.

1        36. The device as set forth in Claim 35, wherein the means for compensating the  
2 output signal vector includes means for generating the plurality of tap matrices based on a  
3 plurality of delayed tap matrices and the product of the error vector signal and the  
4 delayed input signal vector.

1        37. The device as set forth in Claim 36, wherein the means for compensating the  
2 output signal vector includes means for generating the output signal vector based on the  
3 product of the delayed tap matrices and the delayed input signal.

1        38. The device as set forth in Claim 33, wherein compensating the output signal  
2 vector includes canceling echo from the input signal vector.